COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

October, 1947

A semi-outdoor power station in Florida

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Generating Station Auxiliaries ▶

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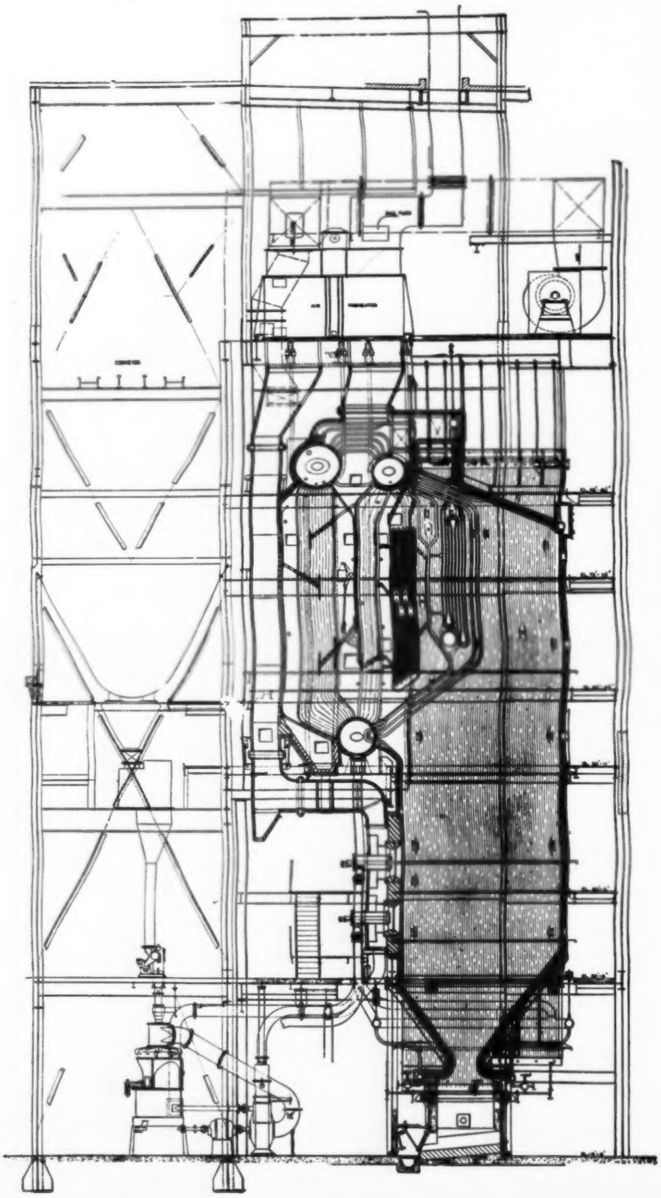
THE CONNECTICUT LIGHT & POWER COMPANY



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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINETEEN NUMBER FOUR

CONTENTS

FOR OCTOBER 1947

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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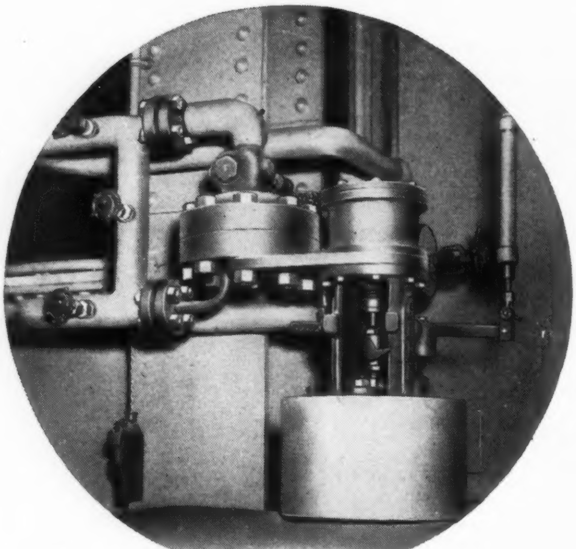

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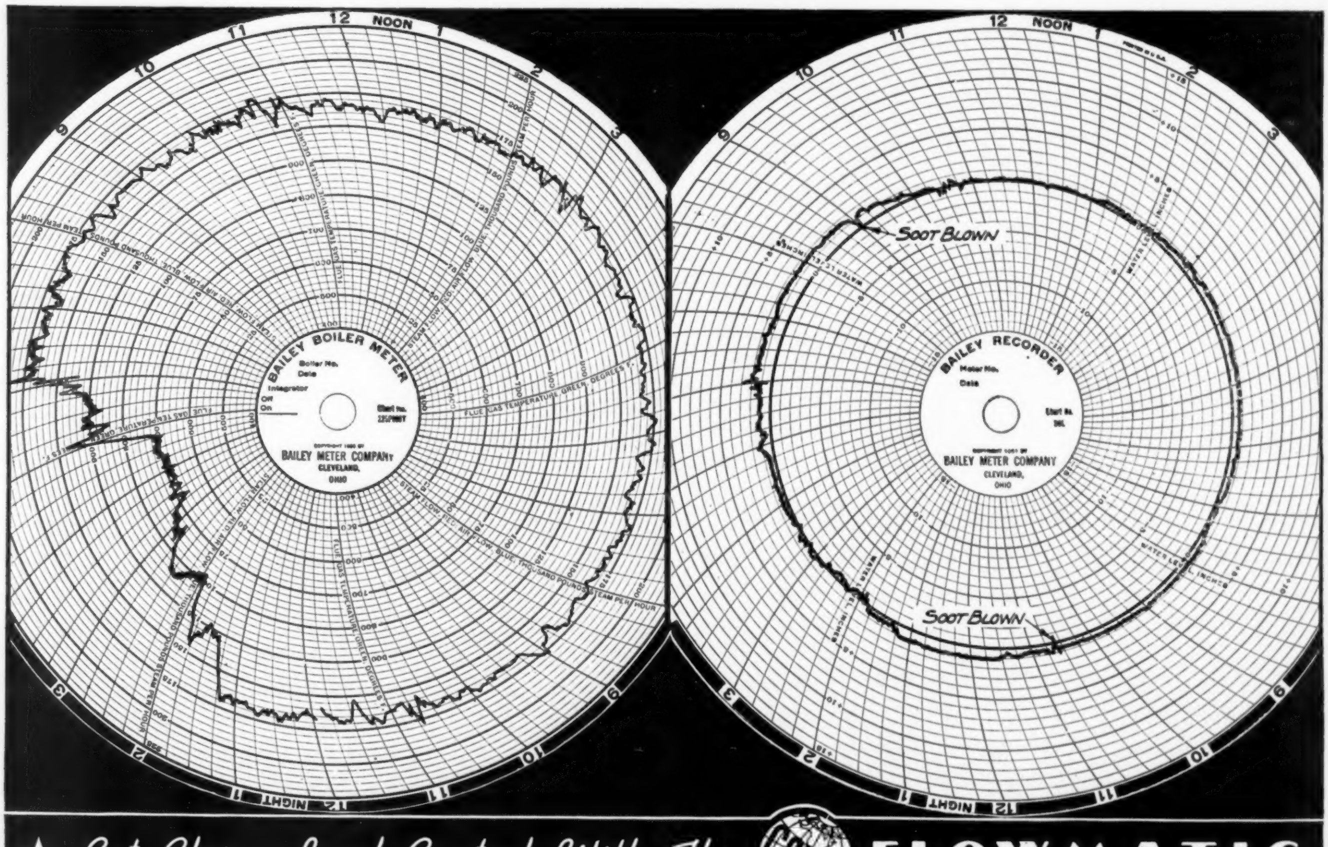

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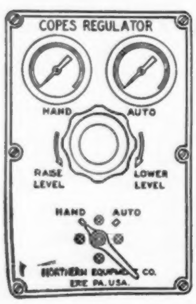

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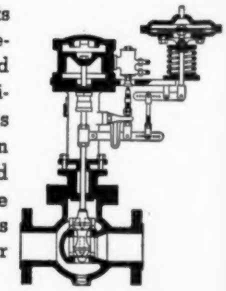

EDITORIAL

Synthetic Oil Receiving Wide Attention

Demand for petroleum and petroleum products now exceeds that during the war and is increasing at a rate several times faster than new oil reserves are being discovered. In fact, drillings during the last few years have been most disappointing and have increased the known reserves only about ten or twelve per cent since 1940. This has led to much thought and development work being devoted to means of producing gasoline and various grades of oil from other than natural petroleum; in other words, from coal, natural gas and shale.

Pilot plants have been built both by private interests and by the government, the outgrowth being that several commercial installations are now in the design and construction stages. Two of these in the Southwest will employ the gas-synthesis process and another in the East will produce oil from bituminous coal. Depending on their experience and economic success, it is anticipated that a number of such plants will be laid down in the next few years. Oil from shale has not yet passed the pilot-plant stage.

Although we are now importing much petroleum to supplement the domestic supply, and American oil companies have substantial interests in the Near East fields, from the standpoint of national security such supply is not dependable. Germany early recognized the fallacy of dependence on imported oil and developed both the Fischer-Tropsch and the Bergius processes for the synthesis of oil from coal and gas, as well as the Lurgi high-pressure process for producing gas from coal. It was the product of these processes that kept the German army mobile for several years.

Technical details of German experience became available to American engineers and chemists upon occupation by our forces and the German processes are reported to have now been modified to meet our conditions with a view toward rendering the products competitive with those from natural petroleum. These modified processes form the basis of the research work now going on in this country.

An alternative means, which holds sufficient promise to interest the U. S. Bureau of Mines, is underground gasification of coal in the mine and subsequent use of the gas, either direct or for the production of oil. So far, however, this has not yet progressed beyond the experiments at Gorgas, Ala., a brief report on which appears elsewhere in this issue.

Although the production of oil from natural gas would in effect, more than double our known petroleum reserves, in the final analysis it is coal and shale, amounting to over 98 per cent of the nation's fuel resources, that must be depended upon to supply the bulk of the not too distant oil demands; providing, of course, that substantial new oil discoveries are not made in the Western Hemisphere.

Incidentally, it is worth noting that the document recently signed in Paris by sixteen European nations, setting forth their needs under the Marshall Plan, is reported to have contained an item of five hundred million dollars worth of petroleum in 1948 and a total of more than two billion dollars worth in the next four years. It is not clear as to the source of this oil we are asked to supply, but in any event it is likely to affect our own fuel situation.

The Fuel Economy Conference

Aside from emphasizing the war's impact in bringing about a general dislocation of the world's fuel supply, the group of papers submitted by the various national committees at the recent Hague Fuels Conference showed what it had been possible to accomplish under adverse conditions with poor quality and substitute fuels. Although many of these substitutes represented passing expedients, much valuable experience was gained through their use, and especially in burning low-grade fuel high in ash and moisture content.

From present indications economic recovery in Europe is likely to take a long time during which fuel supply will continue to be seriously affected, both from the political and the production standpoints. In fact, it is doubtful if a semblance of the pre-war fuel status can ever return, and what were formerly regarded as inferior coals will become the predominant and accepted grades. Thus wartime operating and design experience is invaluable for the future.

Despite periodic labor disturbances, advance in prices, scarcity in premium grades and some deterioration in the general run of available coals, the United States has been most fortunate compared with many other countries. Nevertheless, it behooves us to profit by their experiences as related in the above-mentioned reports.

It is the general consensus of those who followed the proceedings that the Fuel Economy Conference, which was held at the Hague as a Sectional Meeting of the World Power Conference, made an important contribution to a better understanding of one of the basic factors in the industrial rehabilitation of Europe.

Power Conference Reports on the WORLD FUEL SITUATION

AT THE Fuel Economy Conference of the World Power Conference, held at The Hague, September 2–9, National Committees representing various countries reported on their respective fuel economies since 1939. These reports, including fuels of all kinds, in addition to reviewing wartime expedients, reflect the impact of the war on the current fuel situation which in most cases is basic to recovery of normal economic conditions. Brief abstracts of these individual reports follow.

These reports emphasize the extent to which internal economies and living conditions in most countries are dependent on fuel, and the fact that few are self-sufficient in this respect. The dislocation in the world's fuel supply brought about by the war also adversely affected those countries not directly involved and made necessary the use of various substitute fuels. Readjustment of fuel supply is still far off.

Great Britain

The British report goes into considerable detail concerning measures adopted during the war period to conserve fuel, the decreasing output of coal due to drafting miners, the ever-increasing industrial demand and the use of substitute fuels and inferior grades of coal with their attendant difficulties.

From 1938 to 1945 the output of coal fell from 226,993,000 tons to 174,543,000 tons; wage earners employed by the collieries dropped from 781,700, to 708,900; and the output per wage earner per shift from 1.12 to 1 ton. The main reason for this decline in total output was undoubtedly the loss in manpower during the first two war years, due to enlistments in the military services and to those going to various war industries. An attempt was made in 1942 to rectify this situation, but inexperience of the newcomers, coupled with absenteeism and increased average age, failed to restore the previous level of output; in fact, it barely checked the decline during the remaining war years and output has since continued downward.

It became necessary, under government pressure and control, to increase the use of inferior fuels and this resulted in many operating difficulties. Despite a subsidy on gas oil to save coal, the tonnage of coal used by the gas industry rose from 19.3 million tons in 1939 to 21.1 million tons in 1945. Moreover, as gas coals have been in short supply, much domestic coal has been diverted to that use. Also, the coal consumption for public supply of electricity rose from 15.9 million tons in 1939 to 23.5 million tons in 1945. To meet this increased demand pressure was exerted on the power companies to use more duff, slurry and high-ash slack. During this period the railways also increased their annual demand from 13 million tons to 14 million tons. Throughout the war much creosote pitch was burned as an alternative to heavy petroleum oils.

Consumers have been encouraged to use coke wherever possible in place of other fuels and coke breeze has been employed to a considerable extent within the limits of its supply and suitability of the plant to its use.

The situation mentioned still continues and the heavily increased demands arising from post-war reconstruction are likely to bring about difficult conditions this coming winter. The deficiency between supply and demand makes certain that continuance of restrictive measures will be necessary. Priority for industrial consumers engaged in export trade must be decided by the Regional Boards under control of the Board of Trade.

The "Control of Fuel" order, initiated in 1942, is still in force. This not only prohibits waste of fuel, but also prohibits its uneconomical use and gives the Minister of Fuel and Power the authority to direct how fuel may or may not be used. Offenders are liable to prosecution.

Among the prohibitions still in force are the use of fuel for advertising purposes, including shop-window lighting or outdoor decorative lighting. Street lighting is restricted to 50 per cent of that used in 1939, and use of fuel for central heating plants is prohibited between April 17 (May 8 in Scotland) and October 31. This applies to most non-industrial premises, excepting small private houses, hospitals and schools. Except on premises serving meals at night, night firing of central heating or hot-water plants is prohibited at any time of the year. Other restrictions apply to heating greenhouses, other than those growing tomatoes.

Although the aggregate fuel consumption of the major coal-using industries, such as gas works, electric generating plants, coke ovens, railways, collieries, and the iron and steel industry, exceeds that of general industry, the scope of further economy among them is not as great. That is, since coal has been one of the major raw materials in those industries, far greater attention has been paid to its efficient use than in many other industries, especially by the larger plants.

France

Before the war France ranked fifth among the coal-producing countries, its output in 1939 having been over 50 million tons, which decreased to 26 million tons in

1944 and rose again to 35 million tons in 1945. Despite this, her national coal resources are very limited, and she imported large amounts of coal, up to 22 million tons in 1938. During the war years the extraction of solid and liquid fuels, the manufacture of synthetic fuels and the production of power were all disorganized by military demands on manpower, enemy occupation, bombing, etc. The daily output per miner decreased from 1.28 tons in 1939 to 0.69 ton in 1944. Since the war, output has slowly increased, with 40,000 German prisioners of war working in the mines, but it had reached only 0.89 ton per day by January 1946. One of the principal drawbacks to increased production is lack of modernization and the need for repairs of mining equipment. A thorough reorganization of the coal industry is necessary in order to bring up production.

French coal, in general, is dirty and friable, and out of every 1000 tons mined, only 570 tons represent marketable material. The poor quality of coal was accentuated during the war and substantially increased maintenance on equipment. This, together with damage from bombing, greatly reduced availability of equipment. The fuel consumption per net kilowatt-hour output of electric utilities therefore increased from 1.1 lb in 1939 to 1.32 in 1942 for the stations in the Paris area, and from 3.09 to 3.97 in other sections.

The annual electrical output of France's 250 generating stations is around 20 billion kilowatt-hours, which is slightly less than half the total demand, the remainder being supplied by hydro power. Electro-chemical and electro-metallurgical industries are by far the largest consumers of power.

New Power Plant Extensions

With a view toward improving the economy of power production, a technical commission has recommended the renovation of steam stations to include large high-pressure, high-temperature, pulverized-coal-fired boilers and turbines of 40,000 kw, except in the Paris region where 60,000- and 100,000-kw units will be adopted. Boiler pressure of 80 kg per sq cm (1138 psi) and steam temperature of 510 C (918 F) are recommended; although in some installations now under construction 1400 psi is being employed. Reheating, the report points out, would lead to 4 or 5 per cent increase in efficiency, but its use in France is considered with some reserve because of flexibility considerations.

The most important center of French petroleum production is Pechelbronn which, before the war, supplied more than 70,000 tons annually. This was reduced to about 60 per cent by 1945. Some oil is also extracted in southern France. However, before the war France imported around $8^1/_2$ million tons of crude oil annually, 38.6 per cent being imported from Iraq and nearly 35 per cent from the United States

France today remains dependent upon coal imports. She is unable to procure them from England, owing to the latter's insufficient production and shortage of transportation facilities makes it difficult to obtain coal from Poland and Indo-China. The question of German coal remains confused and it is impossible to estimate the capacity of Russia to export. Therefore, French economy finds itself dependent upon fuel imports from America, the extent of which will have a decisive influence upon French recovery.

Germany

The report on Germany was prepared under the auspices of the Allied Control Commission. It gave figures from 1939 through 1943 during which period production of coal increased from 198,748,000 tons to 268,863,000 tons and the number of men employed from 478,019 to 764,655. By the end of 1943 the forced labor in mining had grown to 39 per cent, but probably because of this high percentage of forced labor, as well as war damage, the 1944 output fell to 240,243,000 tons. Pre-war prices were maintained generally through April 1946 for domestic consumption, although export prices advanced.

In the years immediately before the war, the coke-oven gas-grid system of Germany was progressively developed until the whole of the surplus coke-oven gas, beyond that needed for heating the ovens, was being collected for distribution over a large area. With the outbreak of war, however, such heavy demands occurred that a shortage of gas ensued; but by 1940 the increased demand was met and, notwithstanding the heavy air raids, gas production in western Germany was not only maintained, but increased. Also, the gasification of brown coal with steam and oxygen under 20 to 30 atmospheres pressure (by the Lurgi Method) holds an exceptional position and yields in one operation a high quality town gas for "grid" gas supply.

In Germany hard and brown coal provide in about equal proportions the most important source of power, the output of which rose from about 80 billion kilowatt-hours in 1941 to 95 billion in 1944.

The high demands on the coal mining and power industries during the war gave special importance to the economic use of fuels with high ash and high moisture contents.

The grate type of furnace was found most adaptable to variations in fuel and, in its several forms, is capable of burning coal containing up to 40 or 45 per cent ash. A novel development is the Duerr-Ruprecht grate which consists of a flat grate on roller bearings with an inclination of 10 to 15 per cent which is lifted at regular intervals and after rolling down a plane hits a stop. By this movement the fuel layer is rearranged, the smaller and more inflammable particles moving down and the larger ones moving up, thus improving combustion.

A disadvantage of these grates is that they are limited in size and output, for which reason pulverized coal has provided the best solution where large outputs are involved.

Use of the beater type mill for hard coals with high ash content makes necessary a careful examination of all factors influencing economy, owing to the higher power consumption and increased wear.

Increasing use of high-ash coal has led to greater use of slagging-bottom furnaces for large pulverized-coal-fired units.

During the war high power demands made it necessary to utilize brown coal of high ash content and low calorific value. For pulverizing such coal an admixture of sand was found necessary. Also, special investigations have been made as to burning salt-bearing brown coal containing 20 to 40 per cent of soluble alkaline salts. The low melting point of these constituents has led to difficulties, but some success has been achieved by the addition of SiO_2 and Al_2O_3 in order to raise the ash-fusion temperature.

Netherlands

Here coal production reached its maximum in 1938 with over 13 million tons which dropped to a little more than 7 million tons in 1944. In addition, coal was both imported and exported, the home production slightly exceeding the home consumption.

Prices rose during the four years of enemy occupation only about 30 per cent, but a great increase in price came after liberation. The price index for electricity and gas exceeded that for coal, but it was in no way sufficient to serve as a compensating influence of restrictions on consumption.

Strict control of fuel supplies was in effect throughout the war, during which Germany appropriated much fuel for itself and for Dutch industries compelled to perform war work. For this reason there was no incentive to improve efficiency in fuel utilization.

Denmark

Prior to the war, pit coal and coke imports averaged annually about 4 and $1^1/_2$ million tons, respectively. The annual production of domestic peat ranged from 300,000 to 400,000 tons and that of brown coal about 50,000 tons. Considerable oil was also imported. With Germany's occupation of Denmark in 1940 the import situation changed completely and it became necessary to step up the peat output to 5 or 6 million tons and brown coal to over a million tons. This was augmented with forestal exploitation of wood equivalent in heating value to about 200,000 tons of oil.

Peat reserves still untouched amount to about 150 million tons, corresponding in value to about 60 million tons of pit coal; and approximately 26 million tons of brown coal remain.

To permit utilization of these poor grades of domestic fuel in steam power plants various procedures were tried with minimum alterations to existing equipment. Even at present Denmark is badly lacking in imported fuel and it is still necessary to utilize reserves of domestic fuel.

Norway

Production of electricity in Norway is almost entirely from water power, the total for 1945 being a little more than ten billion kilowatt-hours, corresponding to 3320 kw-hr per inhabitant per year. These figures were exceeded in 1944, for when the Germans evacuated northern Norway at the end of that year, they destroyed many power plants, dams and transmission lines in that region.

Before the war the yearly requirements of coal and coke amounted to about 3,300,000 tons of which 300,000 tons was produced by Norwegian mines and the remainder imported—70 per cent from England and the balance from Germany and Poland. During the period of enemy occupation, however, coal was imported only from Germany. This amounted to only about half that of the pre-war tonnage. As a result, practically all use of coal and coke for household purposes was forbidden, although hospitals and certain other institutions were granted small rations. Railroads, on the other hand, increased their consumption of coal, this being due to the increased demand for transportation by the occupation forces.

Reduction of coal and coke in industry was partly compensated by use of wood and peat, the allocations being by zones and by industries. For instance, the pulp and paper industry had a 50 per cent cut in its fuel allowance due to the decreased export of this commodity. Wood and peat were also used for household heating and as generator fuel for motor transport. By 1945 the annual wood consumption had increased to 230,000 cords, and a peak in peat production was reached in 1943 with an output of over 2 million cubic meters, corresponding to about 300,000 tons of coal and coke.

The limited quantities of available fuel stimulated efforts to improve efficiency, which, however, were impeded by the ever-changing quality. Considerable research on firing methods resulted and it often became necessary to alter furnaces and firing equipment, such as the introduction of a prefiring system and the use of scrapers to secure the most suitable fuel distribution on chain-grate stokers.

Sweden

The output of hydroelectric energy in Sweden increased from 8,125,000,000 kw-hr, corresponding to 1200 kw-hr per inhabitant in 1939, to 13,100,000,000 kw-hr, or about 2000 kw-hr per inhabitant in 1945. Fuel shortages during and following the war made it necessary to reduce the use of electricity produced by steam plants whose output during this period fell by more than half. Many industrial plants burned wood, wood waste and other substitutes.

At present hydro power is transmitted over long distances from the northern to the central and southern sections of the country by 200-kv transmission lines. Much electric power is employed for electro-chemical and electro-thermal industries, as well as for heating. Electric boilers account for over a billion kilowatt-hours annually.

During the pre-war years Sweden imported about 8 million tons of coal and coke annually, of which about half came from the United Kingdom and the remainder from Poland, Germany and Holland. However, the coal imports from England were entirely cut off in 1940. Present imports of coal and coke are now only about 1,600,000 tons. About 1,200,000 tons of domestic peat are produced annually. Considerable quantities of this are used as household fuel, in briquet form; also large amounts are burned by industrial plants and railways in the southern part of the country.

During the war gas producers, operating on wood or charcoal, were generally employed for traction purposes, such as buses, automobiles and farm tractors. Alcohol-gasoline (shale gasoline) mixtures were also used for some cars.

The scarce supply of fuel has resulted in greater interest, by all classes of consumers, in improving economy of use and has stimulated research in that direction.

Finland

In so far as power is concerned, the major portion is produced by hydro, although cession of territory to Russia reduced the potential capacity by about one-fourth. Of a total electric consumption of 2,942,000,000 kw-hr in 1946, 2,483,000,000 kw-hr was produced by hydroelectric plants. At the beginning of 1947 the total installed steam-plant capacity, including industrials, was 465,000 kw. Eleven new hydroelectric plants, aggregating 373,000 kw are now under construction.

Due to greatly reduced coal imports during and since the war the consumption of wood for fuel has increased

$2^1/_2$ times. The output of peat has also risen but not sufficiently to be of much importance in the total fuel requirements. Estimated fuel needs for the current year, of all kinds, including coal, oil, coke, peat wood and waste, expressed in terms of coal, were 4,685,000 tons, and it is predicted that the importation of 1,500,000 tons of coal per year will be necessary to re-establish pre-war economy.

Ireland

The only substantial fuel reserves in Ireland lie in peat bogs, a considerable portion of which has long been cut and used for domestic purposes. During the war this output was stepped up about 50 per cent to over 5 million tons per annum. Coal for power and industrial use had long been imported from England, and during the war not only were these imports cut radically, but the quality deteriorated greatly. While fuel conditions in northern Ireland were similar to those in England, the supply to southern Ireland fell from $2^1/_2$ or 3 million tons annually to about 750,000 tons and this consisted largely of semi-anthracite duff which was difficult to burn. As a result, electric utilities, gas works, railways and industrials were seriously handicapped and services had to be greatly curtailed.

Coal consumption of the electric utilities rose from 1.58 lb per kw-hr in 1939 to 2.59 lb in 1945, and the price per ton of coal increased from 23s to 66s, despite the low quality. Fortunately, the Shannon water power development was able to supply considerable power.

Switzerland

Despite an abundance of hydroelectric power resources about half of which have been developed, Switzerland remains essentially dependent on imported coal. In 1938, 53 per cent of the coal imports came from Germany, 16 per cent from France, 13 per cent from Holland, 8 per cent from Great Britain, 4 per cent from Belgium, 4 per cent from Poland, and 2 per cent from other countries. Cheap water haulage was responsible for the predominance of Ruhr coal. In 1946 the coal imports from Germany had fallen to 2.7 per cent of the 1938 total consumption.

It was only through a rigorous and prudent rationing policy that Switzerland escaped a breakdown of her national economy in 1945. Through these measures coal stocks at the end of that year were still about 780,000 tons, equivalent to about 20 per cent of the 1938 consumption. Fuel rationing was dictated by the need for assuring in the following order, national defense, agriculture (chemical fertilizers), other food supply, and sufficient industrial capacity to make certain subsistence of the workers.

Technical measures were directed toward elimination of waste, modernization of equipment, automatic controls, and the design and construction of equipment for utilizing low grade fuels. Also, new uses for electric power (generated by hydro), such as thermo-compression, were pushed.

Portugal

Portugal is not rich in mineral fuels and those which exist are of poor quality. Before the war she imported coal principally from Britain but has now been obliged to seek other suppliers, in particular North Africa. The price of imported coal has increased to about three times that of the last pre-war year. Supply and distibution of coal and charcoal is still in the hands of the Coal Trade Control Commission.

The increase in output required of domestic coal producers has been reflected in a still poorer quality of the product and various means have been adopted to permit its more efficient use. These included burning in combination with oil.

From August 1941 on, the government imposed a severe rationing of all petroleum products; and during this period of oil shortage, attempts were made to use a substitute motor fuel consisting of a mixture of petroleum spirit, alcohol and turpentine. Experience showed satisfactory results with as high as 50 per cent turpentine. At the same time the government endeavored to charter and purchase tankers, as a result of which the fleet now formed is expected soon to suffice for the country's immediate petroleum needs.

Australia

While Australia is entirely dependent on the import of oil and petroleum products, she possesses her own coal resources. Coal production, however, has been hampered by labor shortages, strikes and absenteeism, and there has been considerable opposition to mechanization. The average number of days worked in New South Wales coal mines was 209 in 1939 and 213 in 1944.

During the war the resulting shortage of coal necessitated the imposition of restrictions on the use of electricity for non-essential industries.

Coal prices have advanced and a consequential rise in cost of power on by-product fuels derived from coal has occurred. This has been accompanied by increases in the prices of other fuels.

In addition to bituminous coal, Australia possesses considerable brown coal having a moisture content up to 64 per cent and a gross heating value of 4000 Btu per lb. This has been used by the State Electricity Commission of Victoria since 1924 and more recently development work has proceeded on the use of raw brown coal for industrial boilers, the most satisfactory results having been obtained with spreader and screw-type underfeed stokers. Conversions to use of brown coal on traveling-grate stokers have not been extensive because of the necessity of rebuilding the furnace settings. Also, briquettes containing 13 per cent moisture and of 9500 Btu per lb heating value have been produced from brown coal for industrial and domestic use.

Argentina

During the war period Argentina's fuel imports shrunk from 40 to 6 per cent of her total pre-war consumption. This situation was met by increasing the domestic production of crude petroleum from 2,663,251 metric tons in 1939 to 3,500,000 metric tons in 1945; by trebling the output of wood and charcoal; by using as fuel the country's surplus grain production amounting to some three million tons annually; by increasing the production of solid mineral fuels (asphaltite and coal) from zero to over 122,000 tons; and by rationing the consumption of fuels of all kinds.

In general, the restrictions on the use of fuels and electric power during the war period were borne without seriously affecting industrial development and increased

consumption. Industrial power plants in 1939 had a capacity of 669,000 hp and consumed 18 per cent of the oil. Installed electric utility capacity during the same period increased only slightly but the output increased from 2,358,600 kw-hr in 1939 to 2,926,500 kw-hr in 1945. Of this total 80 per cent is credited to the greater Buenos Aires area.

Austria

In 1937, the last year of Austrian independence, a total of 6,752,188 tons of solid fuel was used, of which approximately half was home produced and the remainder imported, largely from Czechoslovakia, Poland and Germany. By 1943, due to stepped-up war production, and an influx from the Reich, the total consumption had risen to over 14 million tons, of which upper Selesia and the Ruhr supplied about 40 per cent; but by 1946 the total had dropped to 4,500,000 tons, of which half was imported. This drop was due both to a decrease in home production and to the extreme difficulty in importing coal from abroad.

Austria will, in the future, always have to depend on imports of high-grade coal, as the home production, consisting mostly of lignite, cannot meet the demand. Large reserves of water power which are already being developed to a limited extent will help meet the power demand. If it were possible for the whole of Austria's indigenous oil to be utilized in her economy, some reorientation of the consumption of various fuels would be possible, but her extensive oil wells and refineries are at present controlled by the Soviet occupation authorities, and further exploitation on a large scale is held back pending final decision on the question of ownership. Furthermore, there are added difficulties in obtaining the necessary materials for the conversion of existing fuel-burning equipment among the consumer groups.

Czechoslovakia

During the period of German occupation coal mining in Bohemia and Moravia, due to their strategic geographical locations, was greatly fostered by allocations of labor, and production was increased by about 50 per cent. At the same time drastic restrictions on coal use and fuel rationing were put into effect.

The occupation authorities also exploited the power stations and gas works, without increasing their capacity or carrying out adequate maintenance. As a result, a two-year plan of rehabilitation and new power construction is now under way.

United States

In summary, the United States National Committee states as follows:

"During the war the basic conditions requiring fuel economy arose from the diversion of normal supplies to military uses and the greatly expanded requirements of fuel for war industry. Fuel oil and its derivatives were principally affected. Since the end of the war, most of the difficulties which were experienced have disappeared, except for the temporary effects of labor disputes and price maladjustments. At present practically all measures which had been in force to limit the usage of various types of fuel have been eliminated, and efforts to promote the economical utilization of fuel are fundamentally based on the costs and economics involved, rather than the availability of supplies."

Significance of Temperature in Titratration of Iodine with Winkler Test for Dissolved Oxygen

The sensitivities of various starches were examined at temperatures ranging from 33 to 105 F to determine the optimum temperature conditions for the starch-iodine reaction in the Winkler test for dissolved oxygen at low concentrations. The starch-iodine reaction was found to have its maximum sensitivity at a temperature of approximately 50 F. Owing to the difficulty of cooling samples to the required temperature, the authors suggest that when determining very low oxygen concentrations an alternative to the Winkler procedure be employed.

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SEVERAL workers in investigating the Winkler test for small quantities of dissolved oxygen have noted the decrease in sensitivity of the starch-iodine reaction with increase of temperature. General recommendations have been made to cool the sample prior to titration, but no specific temperature range is given for optimum sensitivity of the starch-iodine reaction.

Yoder and Dresher (8)[1] state that the starch sensitivity temperature curve is quite flat at 70 F. They also remark, however, that if the temperature of the sample prior to titration is higher than 85 F it should be cooled in ice water. Alfano (1) states that the sample should be cooled as much as possible, preferably to 40 F. The American Public Health Association and the American Waterworks Association in their Standard Methods (2) advise that boiler waters should be cooled to 70 F during sampling. Bond (3) also quotes 70 F as the maximum permissible temperature.

In view of these discrepancies in the recommended optimum temperature range for the starch-iodine reaction and the possibility that these differences might have been due largely to the starch employed, the authors undertook the following investigation:

Seven different starches, representative of the types used in laboratories in Southern Africa and abroad, were employed for this work. It might be noted that we are informed by the manufacturers that both British Drug Houses' AnalaR and Baker's Analyzed soluble starches are made from potato starch.

To white porcelain dishes were added 100 ml of freshly boiled distilled water at temperatures increasing in steps of approximately 5 deg F from 33 to 105 F. To each dish were added 0.5 gm of potassium iodide and 1 ml of 0.5 per cent starch solution prepared according to the standard *methods of the American Public Health Association* and American Waterworks Association. The function of the potassium iodide was to furnish the iodide ions necessary for maximum sensitivity of the starch-iodine reaction (6).

From a burette 0.001 *N* iodine solution was added until the first visible blue color was observed. In the volume of solution used, 0.50 ml of 0.001 *N* iodine solution is equivalent to the iodine released in the Winkler test by 0.028 ml oxygen per litre.

Dissolved Oxygen Limits

It is generally accepted that the dissolved oxygen in modern, medium- and high-pressure boilers should not exceed 0.025 ml per litre. For this reason our study of the starch-iodine reaction has been confined to the quantities of iodine released by 0 to 0.03 ml oxygen per litre.

The results are tabulated in Table 1 and depicted graphically in the accompanying curves. In all cases the results are the mean of several determinations. The latter, however, did not vary significantly from one another.

It will be noted that with starches numbered 1, 2, 3, 5 and 6, the sensitivity increases slightly from 33 F to reach a maximum somewhere between 40 and 50 F, after which the sensitivity decreases with further increase in temperature. Starches 4 and 7 maintain a constant sensitivity, from 33 to 46 F in the case of No. 7 and to 58 F with No. 4, after which they too decrease in sensitivity with rise of temperature.

The decrease in sensitivity of starches 1, 2, 3, 5 and 6 at very low temperature could be explained by the slowness of reaction at the lower temperatures. Hille-

[1] See references at end of article.

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Table 1. Sensitivity of the starch-iodine reaction at varying temperatures with different starches

Temperature	1 B.D.H. Rice Starch		2 B.D.H. Potato Starch		3 B.D.H. Maize Starch		4 B.D.H. Soluble AnalaR		5 George & Becker Soluble Starch		6 Baker's Analysed Soluble Lintner		7 B. Owen Jones Soluble	
°F	a	b	a	b	a	b	a	b	a	b	a	b	a	b
33	0.15	0.008	0.10	0.006	0.20	0.011	0.20	0.011	0.20	0.011	0.20	0.011	0.10	0.006
35	0.12	0.007	0.10	0.006	0.16	0.009	0.20	0.011	0.16	0.009	0.18	0.010	0.10	0.006
40	0.10	0.006	0.09	0.005	0.15	0.008	0.20	0.011	0.13	0.007	0.16	0.009	0.10	0.006
45	0.09	0.005	0.07	0.004	0.15	0.008	0.20	0.011	0.10	0.006	0.15	0.008	0.10	0.006
50	0.05	0.003	0.05	0.003	0.15	0.008	0.20	0.011	0.09	0.005	0.18	0.010	0.13	0.007
55	0.05	0.003	0.05	0.003	0.18	0.010	0.20	0.011	0.09	0.005	0.21	0.012	0.16	0.009
60	0.10	0.006	0.05	0.003	0.21	0.012	0.20	0.011	0.09	0.005	0.27	0.015	0.20	0.011
65	0.15	0.008	0.07	0.004	0.23	0.013	0.23	0.013	0.10	0.006	0.30	0.017	0.23	0.013
70	0.16	0.009	0.10	0.006	0.27	0.015	0.25	0.014	0.13	0.007	0.35	0.020	0.29	0.016
75	0.20	0.011	0.13	0.007	0.32	0.018	0.32	0.018	0.15	0.008	0.41	0.023	0.32	0.018
80	0.25	0.014	0.16	0.009	0.38	0.021	0.38	0.021	0.18	0.010	0.48	0.027	0.38	0.021
85	0.27	0.015	0.20	0.011	0.43	0.024	0.45	0.025	0.23	0.013			0.43	0.024
90	0.32	0.018	0.23	0.013	0.50	0.028	0.50	0.028	0.29	0.016			0.50	0.028
95	0.35	0.020	0.32	0.018					0.40	0.022				
100	0.40	0.022	0.41	0.023					0.50	0.028				
105	0.50	0.028	0.52	0.029										

a. Ml. of 0.001 N iodine required to produce first visible blue color.

b. Oxygen in ml. per litre equivalent to a.

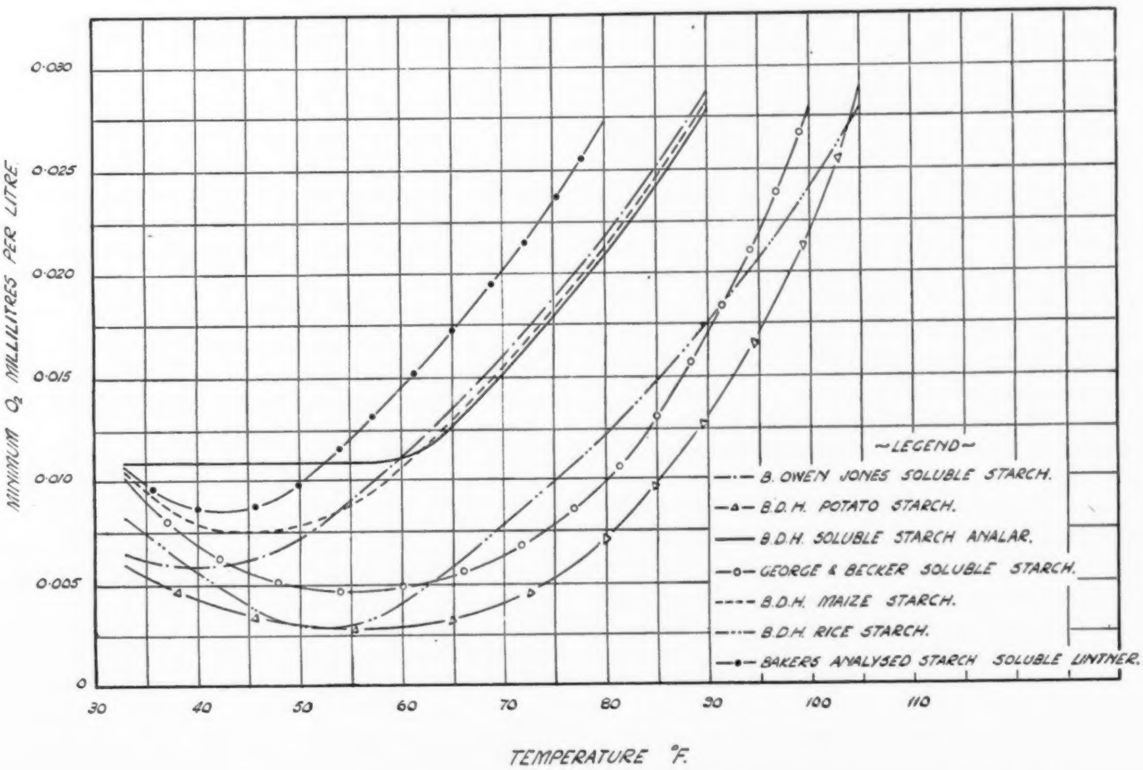
brand and Lundell (5), for instance, state that iodine titrations in ice-cold solutions are undesirable due to the slow rate of reaction at low temperatures. It is difficult to account for the anomalous behavior of starches 4 and 7.

In Table 2 are listed the minimum quantities of oxygen which are detectable at various temperatures by the starches under examination.

It is seen that the starches examined are most sensitive between 40 and 50 F. Our results do not confirm Bond's statement (3) that it is immaterial how far the temperature is reduced below 70 F, although the error introduced by excessive cooling is not great.

As a matter of interest Yoder and Dresher's figures (8) for one range of starches are compared in the accom-

	Temperature at Which Color Forms with 0.015 ml Oxygen per Litre, Deg F
YODER AND DRESHER	
Baker's wheat	110
Baker's corn	109
Baker's arrowroot	80
Pfanstiehl potato purified	77
Merck's soluble Lintner	77
Merck's C.P. soluble purified	75
Baker's C.P. soluble	73
Pfanstiehl soluble Lintner	65
AUTHORS	
B. D. H. potato	91
George & Becker soluble	88
B. D. H. rice	85
B. D. H. soluble AnalaR	71
B. D. H. maize	70
B. Owen Jones' soluble	69
Baker's Analyzed soluble Lintner	61



Sensitivity of Starch-Iodine Reaction

panying tabulation with those we obtained for the starches employed in our work.

Comparison of our results with those of Yoder and Dresher indicates the wide differences in sensitivities of various starches. Excluding the wheat and corn starches tested by Yoder and Dresher, the temperature range at which color forms is approximately the same for both

Table 2. Influence of temperature and starch on minimum quantity of oxygen detected.

	Starch	Minimum Quantity of Oxygen Detectable in ml. O_2/litre						
		33°F.	40°F.	50°F.	60°F.	70°F.	80°F.	90°F.
1	B.D.H. Rice	0.008	0.006	0.003	0.006	0.009	0.014	0.018
2	B.D.H. Potato	0.006	0.005	0.003	0.003	0.006	0.009	0.013
3	B.D.H. Maize	0.011	0.009	0.009	0.012	0.015	0.021	0.028
4	B.D.H. Soluble AnalaR	0.011	0.011	0.011	0.011	0.014	0.021	0.028
5	George & Becker Soluble	0.011	0.007	0.005	0.005	0.007	0.010	0.016
6	Bakers Analysed Soluble Lintner	0.011	0.009	0.010	0.015	0.020	0.027	>0.028
7	B.Owen Jones Soluble	0.006	0.006	0.007	0.011	0.016	0.021	0.028
	Average	0.009	0.007	0.007	0.009	0.012	0.018	>0.023

investigations. We would have expected, however, a closer similarity between Baker's corn and B. D. H. maize starches.

As a further investigation, solutions containing 100 ml of water, 1 gm of potassium iodide, 1 ml of 0.5 per cent starch solution and exactly 5 ml of 0.002 *N* iodine were titrated with approximately 0.002 *N* sodium thiosulphate at 52 F and 81 F. The results are given in Table 3.

The agreement in the last two columns of Table 3 is within the limits of experimental error for this procedure and there seems to be little doubt that a minus error of about 0.01 ml oxygen per litre would be made if the Winkler test is carried out at 80 F instead of 50 F.

Table 3. Comparison of starch-iodine sensitivity with starch-iodine-thiosulphate reaction at varying temperatures

		Ml. of ca. 0.002 N $Na_2S_2O_3$ required		Difference ml. 0.002 N $Na_2S_2O_3$	Difference in terms of O_2 ml./l.	Difference O_2 ml./l. as indicated by Table I
		52°F	81°F			
1	B.D.H. Rice	4.90	4.83	0.07	0.008	0.011
2	B.D.H. Potato	4.90	4.85	0.05	0.006	0.006
3	B.D.H. Maize	4.95	4.83	0.12	0.013	0.013
4	B.D.H. Soluble AnalaR	4.95	4.90	0.05	0.006	0.010
5	George & Becker Soluble	4.90	4.84	0.06	0.007	0.005
6	Bakers Analysed Soluble Lintner	4.90	4.75	0.15	0.017	0.017
7	B. Owen Jones Soluble	4.90	4.83	0.07	0.008	0.014
				Average	0.009	0.011

Contrary to some workers (8) we did not find that the insoluble starches adsorbed iodine which required an excess of sodium thiosulphate to remove the blue color.

Bond's work (3), which was carried out under actual power plant conditions, indicates a slightly greater error for a similar temperature difference. However, we agree with Schwartz and Gurney (7) when they state that it is not advisable to assume fixed values for the sensitivity of a starch as a function of temperature. For this reason our work only indicates the behavior of a particular group of starches under one set of experimental conditions, and in our opinion under no circumstances should Winkler test oxygen figures made at high temperatures be corrected with the aid of temperature sensitivity charts.

The sensitivity of the starch-iodine reaction appears, therefore, to be a resultant of two factors, namely, a decrease of formation and intensity of color with: (*a*) decrease in temperature, probably due to slow reaction rate; (*b*) increase in temperature, owing to the instability of the color complex at higher temperatures.

For most starches the opposing tendencies of these factors result in a maximum sensitivity at a temperature in the region of 50 F.

We do not believe the true shape of the sensitivity curve has been recorded by previous investigators, who did not carry temperatures low enough to observe the decrease in sensitivity at low temperatures.

Precautions for Low Oxygen Concentrations

When determining very low oxygen concentrations in boiler waters with the Winkler test it seems essential to make the final titration at a temperature of about 50 F. Even with the aid of a refrigerator, this is not easily done in most power plants situated in tropical or subtropical climates. It is generally admitted that even extremely low concentrations of dissolved oxygen in boiler waters may be responsible for corrosion in high pressure boilers, and therefore it almost seems that the Winkler test in its accepted form has outlived its usefulness as a routine method for dissolved oxygen in boiler feedwaters.

The final titration might be made potentiometrically thus avoiding the vagaries of starch, or the modifications of the Winkler test proposed by Schwartz and Gurney (7) or that by Haslam and Moses (4) might be substituted. The procedure of Haslam and Moses, wherein dissolved oxygen releases an equivalent quantity of chlorine which is measured colorimetrically with the aid of orthotolidine, seems to be convenient and suited for routine work. This method, which we ourselves employ at present, appears to be coming into wide use in power stations. Unlike the procedure of Schwartz and Gurney, however, it does not eliminate from consideration the oxygen contamination arising from the Winkler reagents. There appears justification for an exhaustive investigation by power plant chemists into the effect of all variables such as temperature, etc., on the procedure.

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Large Generating Unit Goes Into Service at Chicago

A NEW 107,000-kw turbine-generator was placed in commercial operation at the Calumet electric generating station of the Commonwealth Edison Company, Chicago, on September 18. This machine, which is one of the early large post-war units to go in service, required nearly thirty months for planning, construction and installation since the order was placed with the Westinghouse Electric Corporation in March 1945. As will be noted from the photograph, it is of the tandem type and presents a streamlined appearance. It is estimated that this unit would be capable of meeting all the electrical demands of a city of around 220,000 population.

Steam is supplied at 1250 psi pressure and 925 F temperature at the turbine throttle by two 600,000-lb per hr Combustion Engineering steam-generating units. These are tangentially fired with pulverized coal supplied by C-E Raymond bowl mills (4 per boiler), but provision has been made for conversion to gas or oil firing, if desired at some future time. The furnaces are of the slagging-bottom type and both economizers and air preheaters (of the tubular type) are provided. As will be noted in the cross-section, Fig. 2, the superheater is of the horizontal type and located above a slag screen.

The cost of this extension, including building addition, boilers, turbine-generator, electrical equipment and auxiliaries, is said to have exceeded sixteen million dollars, which would be equivalent to a unit cost of approximately $150 per kilowatt.

Installation of this new Calumet unit increases that station's capacity to 294,000 kw and boosts to about 2,400,000 kw the total rated capacity of the stations of the Commonwealth Edison Company and its associated utilities, namely, the Public Service Company of North-

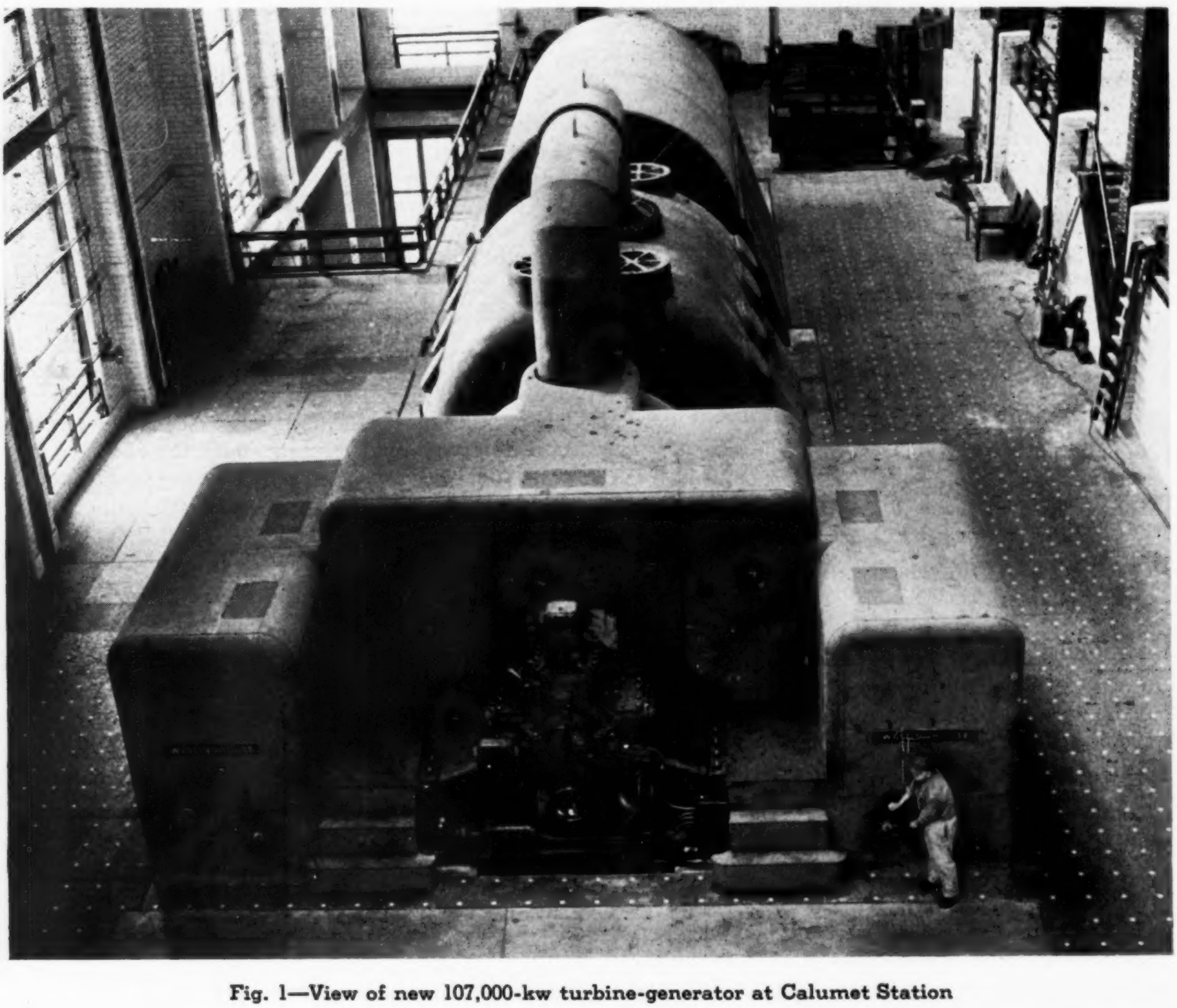

Fig. 1—View of new 107,000-kw turbine-generator at Calumet Station

ern Illinois, the Western United Gas & Electric Company and the Illinois Northern Utilities Company.

A recently announced $200,000,000 expansion program, according to Charles Y. Freeman, Chairman of the Board, will provide for the addition to the power resources of this interconnected system in the next three or four years, another 407,000 kw, which a survey by these companies has shown will be required to enable them to meet the growing electrical demand in the Chicago area.

A 150,000-kw unit for the Fisk Station, Chicago, and a 107,000-kw unit for the Joliet Station of the Public Service Company of Northern Illinois are already on order, and studies are being made for the location of a second 150,000-kw unit. Such studies are necessary well in advance of the actual demand, inasmuch as it now takes three or more years from the time orders are placed to get new capacity of this magnitude installed and ready for service.

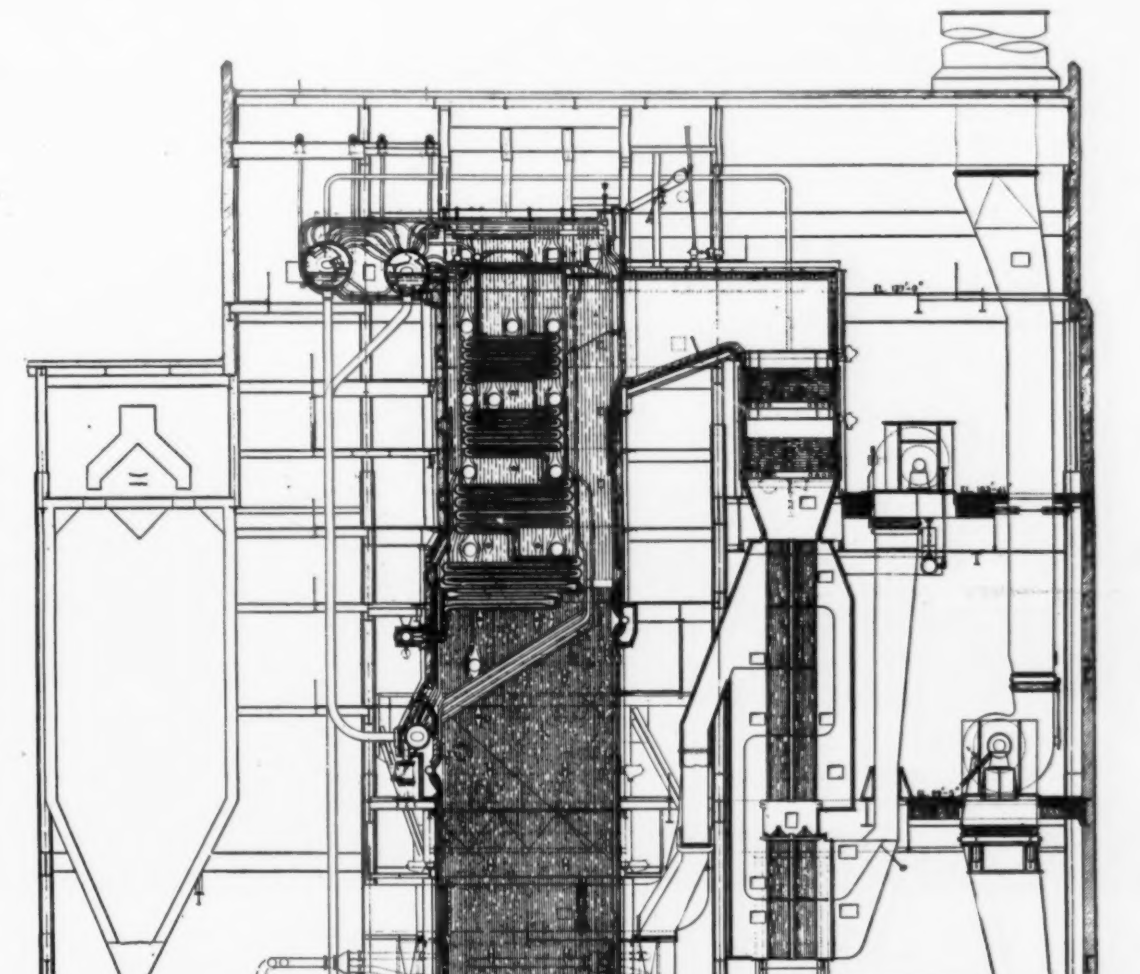

Fig. 2—Sectional elevation through one of two steam generating units


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Generating Station Auxiliaries

These excerpts are from a lengthy comprehensive paper by W. Szwander, presented before several regional sections of the Institution of Electrical Engineers, and are confined to a discussion of power supply for rotating auxiliaries. Included are factors influencing selection, steam versus electric drive, choice between alternating- and direct-current, adaptation to unit station design, sources of auxiliary power, and duplication for reliability.

THE design of an auxiliary system depends on a number of factors, the most important of which are the overall size of the station, the characteristics of the main system which is to be fed by the station, and the principal features of the heat cycle adopted. While the power *installed* in auxiliaries depends on a number of station design features, it will generally range between 6 and 10 per cent of the installed station capacity, although the *actual* auxiliary load will be somewhat less, usually from 4 to 8 per cent of the total energy generated.

A survey of a large number of modern generating stations shows the predominance of all electric drive, exceptions in some cases being steam-driven boiler-feed pumps, auxiliary oil pumps for turbine-generators and standby turbine-driven circulating pumps for forced-circulation boilers.

Steam vs. Electric Drive

The main advantage of steam-driven auxiliaries, namely, their high degree of reliability due to their independence of electric system disturbances or breakdowns of the main turbine-generator, has now lost much of its former importance; because, with modern methods of supplying power to the electric auxiliaries, their reliability can safely be regarded as fully satisfactory. Moreover, the use of steam for auxiliary drives does not, as it might at first appear, solve the problem of starting a station from cold without external power supply; because large modern boilers, particularly those fired with pulverized coal, themselves need large amounts of auxiliary power before steam for other auxiliaries is available.

On economic lines alone, it is difficult to obtain a definite answer in favor of one or the other types of drive. The first cost of steam drive, when the steam pressure and temperature are not too high, is usually lower than that of electric drive. The reason for this is that, while auxiliary turbines with their piping are approximately equivalent in cost to motors and their controls, with steam drive considerable saving occurs on auxiliary transformers and on the reduced rating of the main generating unit and step-up transformers.

On the other hand, the heat consumption per unit of energy used by the auxiliaries is higher when steam drives are used. This is due, not only to the lower efficiency of small turbines, but also to the loss of the cycle efficiency for the main units in which full use cannot be made of bled-steam feedwater heating when the exhaust steam from the auxiliary turbines has to be used for this purpose. Feed heating by exhaust steam from auxiliary turbines is also likely to be less satisfactory than by bled steam, because the available quantities of exhaust steam do not vary with the feed-heating requirements; that is, the inherent self-adjusting features of bled-steam feed heating are lost, and some means of control are necessary with attendant losses.

The final outcome of the economic comparison, taking into account both first cost and heat consumption, may be in favor of either steam or electric drive, depending upon the station load factor, the amount of bled-steam feed heating from the main turbines, the unit sizes of the auxiliary turbines, etc. However, the higher the steam pressure and temperature, as adopted in modern stations and the more numerous the number of bleed points for feedwater heating, the more difficult it becomes to justify steam drive.

In the past few years the inherent advantage of steam drives, from the standpoint of simple and easy speed control, has almost been equalled on the side of electric drive by the development of variable-speed couplings (hydraulic and magnetic), of a-c commutator-type motors, and by the increasing use of variable-voltage d-c systems. All these methods of speed variation are more suited to remote control than is the back-pressure turbine. This is important in view of the wide use of automatic combustion control. Also, such details as safety and sequence interlocks between auxiliary services are more easily arranged with electric drive. Finally, electric drive eliminates the large amount of steam piping associated with steam drive.

A case in which the use of steam-driven auxiliaries can best be justified is that of a topping installation where the existing low-pressure plant has insufficient bled-steam feed heating or none at all. Here the use of exhaust steam from auxiliary turbines for feed heating may contribute considerably toward the improvement of overall plant efficiency.

Alternating vs. Direct Current

For plant auxiliary services, as a whole, it is now general practice to employ alternating current. The principal reasons why in earlier days direct current had many

supporters for this purpose were the possibility of providing a standby in the form of storage batteries, the ease of stepless speed control over wide ranges, and the large degree of immunity from a-c system voltage or frequency disturbances. But with the present high degree of reliability of supplying power to a-c auxiliaries, and with the greatly improved safety of operation of the main a-c systems, due to system interconnection and methods of fault isolation, disturbances on the main system seldom threaten the auxiliary system.

Speed control still remains the greatest advantage of direct current. Incidentally, in modern station practice the variable-speed output control of fans and pumps has become a widely accepted measure for saving auxiliary power. With a-c motors, however, alone or in conjunction with auxiliary devices, practically all speed-control problems can now be solved more or less satisfactorily. To enumerate a few, there are multi-speed, change-pole induction motors, rotor-resistance-controlled slip-ring motors, a-c commutator motors of various types, and squirrel-cage motors used with hydraulic variable-speed couplings or with magnetic couplings.

Despite the foregoing, there are certain applications in which d-c motors still prove best, as for instance, stoker drives, raw-coal feeders, and where a number of motors must have their speeds varied simultaneously. An example of the last-mentioned is the method of controlling boiler auxiliaries in which the speeds of different motors can be varied, not only simultaneously, but also according to predetermined relationships with each other and with the boiler load. Moreover, speed control by means of d-c motors involves, comparatively, the smallest power losses, so that with certain types of load, such as fan load (particularly when mercury-arc rectifiers are used for a-c to d-c conversion) they may be more economical than other schemes of speed control, despite their lower full-load efficiency and higher cost than most a-c motors.

Insuring Reliability

Since any component of the auxiliary system is liable to failure, though with modern equipment this may be infrequent, the only way to insure high reliability is by subdividing and duplicating its elements. In practice this is carried out to a varying degree, depending on the design of the main station components as well as on the individual judgment of the designer. Assuming that all the essential station auxiliaries are divided (that is, are provided as duplicate, 50 per cent rated units, and that the two groups of motors driving the two halves of the auxiliaries are supplied from two independent power sources), it can be safely accepted that a boiler or a turbine will practically never be deprived of more than half its essential auxiliaries. It will, therefore, be able to continue to operate at reduced load throughout any disturbance on the auxiliary system. This applies only to boilers that are designed to operate, at least temporarily, with half their fans at standstill.

The provision of two boilers per turbine can be regarded as partly satisfying the required duplication, but even in this case it is better to arrange the auxiliaries of both boilers so that on each of them only one-half of the auxiliary services is lost in any emergency. This is preferable to accepting the chance of losing one boiler completely because, in such an event, the restoration of normal operating conditions would take much longer and the loss of load during the disturbance would be more severe.

Adaptation to Unit Station Design

Many modern electric generating stations are designed on the unit principle; that is, each main turbine-generator together with its associated boiler or boilers and the auxiliary equipment, is a self-contained entity. Apart from the paralleling of various units on the main busbars, provision is often made for cross-connections between the main steam receivers, and between the suction lines and also the discharge lines of the boiler-feed pumps. The unit principle has permitted the building of stations in consecutive stages without overloading the initial stages with heavy capital charges for equipment that will be common to the complete station, and also without ruling out any fundamental modifications of the steam cycle or other particulars of design in subsequent extensions.

Obviously, the auxiliary system in such cases must be adapted to the unit design. In this respect the use of unit transformers connected to the main generator terminals or of auxiliary shaft-generators is most convenient. Busbar-connected auxiliary house transformers should preferably be installed in unit sizes, corresponding to the needs of the main sets; although economic grounds sometimes favor one or two larger station transformers serving as standby and starting-supply sources for all the units. Independent house turbine-generator sets are very difficult to incorporate into the unit scheme. Nevertheless, layout of the auxiliary system on the unit principle should not be regarded as excluding the possibility of providing emergency cross-connections between the parts of the auxiliary system supplying different units.

Sources of Auxiliary Power

The degree of reliability of power supply for auxiliary services depends mainly on the sources from which that power is derived. In line with the principle of duplication of the auxiliary system elements, as previously discussed, and in view of the fact that no power source is totally reliable, it is good practice when possible to make use of two independent power sources for supplying the auxiliaries. Limiting the considerations to a-c auxiliary systems, there are four possible sources of power—the main station busbars (usually through step-down transformers), the main generator terminals, a shaft generator, and a separately driven house generator.

The first mentioned is the simplest and cheapest solution, but is seldom relied upon in large modern stations as the only supply for the auxiliaries, owing to its susceptibility to system disturbances. However, it is often used as one of two independent supply sources.

Supply of auxiliary power from the main generator terminals represents a trend toward making the auxiliary system more and more independent of disturbances on the main system. That is, in the event of a severe fault leading to isolation of the generator from the busbars, the auxiliaries are not deprived of their power supply, and normal service can thus be restored more quickly. Since the main generator voltage is usually higher than that of the auxiliary system, this arrangement generally includes a step-down transformer. However, an alternate

source of supply is indispensable during the starting period of the main generator.

Deriving power from an auxiliary generator driven direct by the shaft of the main unit provides immunity from main system voltage disturbances, but it is essential to insure that the turbine over-speed governor does not operate at the time of complete loss of load by the main unit. A disadvantage of a shaft generator is the extra initial cost; also an alternative supply for starting periods must be provided.

With an independent house set the auxiliary system is completely immune from disturbances on the main system, and the necessity of transferring load from one source to another during starting of the main unit is obviated. However, as house sets themselves are also susceptible to disturbances, it is not wise to feed all the station auxiliaries from one house set. Disadvantages include higher initial cost than shaft generators and higher generating cost of auxiliary power; they do not fit well into the unit station arrangement; small house turbines are not well adapted to the high pressures and temperatures now employed in large modern stations as they require ratings outside the standard ranges; and non-condensing turbines are seldom applicable, except perhaps in some topping installations, as bled steam from the main unit meets feed-heating requirements. Therefore, few of the later stations employ auxiliary house sets.

Finally, when designing the station, careful planning of the auxiliary system should be carried out at an early stage and all possible future extensions should be kept in view.

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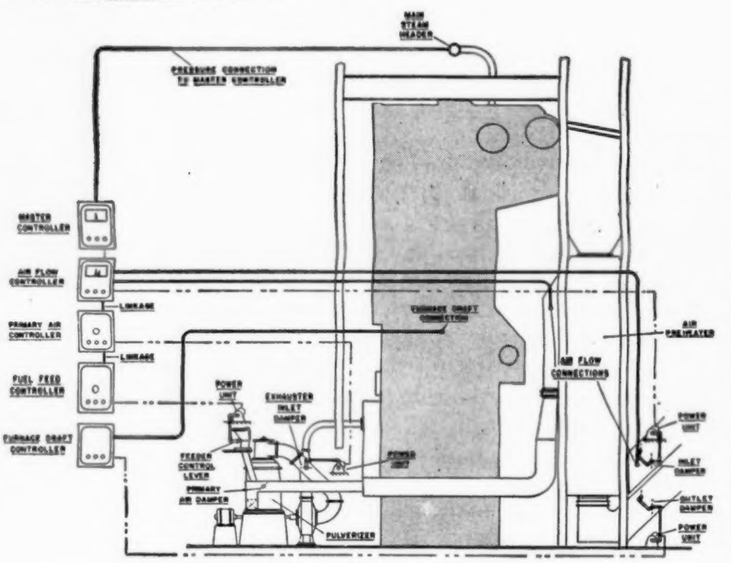

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BARK BURNING METHODS

By J. H. FREIDAY

Combustion Engineering Co., Inc.

A review of the shortcomings of existing methods of burning bark and other wood refuse and suggestions for radical improvements which are now much needed in view of the changed economic situation as pertains to utilization of such refuse.

IN PULP mills, lumber mills and other wood-processing industries, in the past, the problem of bark burning was primarily a disposal matter but with increasing costs of fuel for steam production the efficient burning of bark and wood waste in steam-generating units can become an important factor in reducing steam costs, provided sufficient consideration is given to its utilization.

Such refuse consists of bark and wood cullings that are passed through a hogging machine for sizing, together with considerable quantities of sawdust. Formerly this refuse was employed entirely as fuel, but in present-day practice a larger portion of the log is utilized and processes have been developed by which once waste refuse is now made into marketable products. This applies especially to the sawdust. However, the bark and to a large extent the wood chips continue to serve as fuel.

The moisture content of the bark, as received, is variable and ranges from 60 to 80 per cent for northern mills and 40 to 55 per cent for southern mills. This wide difference is due to the general practice of river driving and wet barking in the North in contrast to rail transportation and dry barking in the South. Moisture after barking can be controlled only by pressing and drying; but the economy of pressing is doubtful unless the moisture content runs over 65 per cent, and the product will still contain about 60 per cent or more water. Moreover, drying is not likely to prove economical unless the moisture exceeds 50 per cent. Bark of 65 per cent moisture content will support combustion and has a heating value of about 3000 Btu per lb, whereas that of dry bark may run over 9000 Btu per lb.

Common Methods of Burning

The process of combustion of bark and wood involves three overlapping stages, namely, evaporation of the moisture, distillation and burning of the volatile matter, and combustion of the fixed carbon.

With bark or hog-fuel burning it has long been the general practice to feed the fuel into a dutch oven or furnace through chutes. This is accomplished either by introduction through one or more spouts or uniformly across the top of an inclined grate using gravity flow.

In the spout-feeding method the fuel is deposited on a flat hearth or flat grates and forms one or more cones with angles of repose of 50 to 55 deg. The fire is usually started with dry shavings and undersized wood refuse from the pulpwood chippers. As wet bark is introduced over such a fire it soon forms a cone blanketing its center and combustion occurs only around the lower edges. Fuel from the top of the pile tumbles down the sides and the center remains inactive.

The top portion of the cone becomes a drying and distillation zone and, due to its shape, it must obtain practically all the heat required for these purposes by radiation alone. The thickness of the fuel bed at the center eliminates drying by air from below. Little heat is obtained by convection since the flames from the lower sides do not impinge on the top of the cone, as they tend to rise vertically and are also pushed away by the vapors coming off the top. This, of course, could be corrected by high velocity air jets properly located in the furnace, but they are seldom employed. In a dutch-oven furnace the top of the cone is so close to the roof that the gas flames seldom sweep the fresh fuel, but flow along the side walls. Heat from conduction is practically nil since there is a definite division between the burning carbon zone and the fresh fuel. Thus drying and distillation at the top of the cone are dependent chiefly on radiant heat.

Radiation can reach the fresh fuel at the top of the cone in two ways—either from the gas flames surrounding the cone or by reflection from the furnace walls. The burning lower fringes of the cone, which appear to be the hottest points, cannot "see" the top of the cone, and consequently the radiant heat from the base can only reach the fresh fuel by reflection from the walls.

Drying and distillation are also taking place on the inside boundary of the burning zones at the lower surfaces of the cone. Some of the vapors from this inner boundary are probably drawn up through the cone where they are chilled by the relatively cool bark above and condense to form the heavy smoke or vapor that can be seen billowing from near the top. This smoke or vapor forms an umbrella which tends to screen the fresh fuel from the radiant heat of the furnace walls and surrounding flames. Thus the top and interior of the cone become ineffective areas.

With ordinary spout feeding the conical pile makes ash and sand removal difficult. The feed must be shut off and the cone burned down before this refuse can be removed either by shaking grates or by means of a hoe. Complete shut downs are customary requirements every one to two weeks, depending on the ash content and the combustion rate.

Lessons from Early Studies

Apropos of the spout feeding and conical pile may be cited a Bureau of Mines study by the late Henry

Kreisinger on lignite fuel beds. Here it was indicated that after the moisture and volatile have been driven off, the char remaining burns only to CO within the fuel bed. Increasing the air flow beyond a certain point will only increase the rate of gasification of fixed carbon without affecting the completeness of combustion. From this it was deduced that all the combustion of volatile matter and half that of the fixed carbon take place above the fuel bed. Therefore, a large proportion of the air required for combustion under such conditions should be supplied above the fuel bed. The apportioning of such air, however, is still a debatable question.

From these observations another factor appears which has bearing on burning bark. This is the distribution of heat release. If the greater part of the fuel burns only to CO in the bed, then a correspondingly small amount of the heat available is released there and the balance must come from the combustion of CO and the volatile above the fuel bed. This means that most of the heat required for evaporation of the moisture and distillation of the volatile matter must come from the zone above the fuel bed. Thus it follows that the longer the time the fuel can be held in the main combustion zone above the bed, the more rapid will be the heat transfer for drying and distillation and the higher will be the possible burning rates.

The second method mentioned, namely, gravity flow over grates, requires special feeding equipment to provide uniform fuel introduction over the width of the grates. These grates are usually set at an average concave slope of about 45 deg in a dutch-oven furnace having a drop-nose arch and tilted bridgewall. The fuel burns well at the bottom of the grates and part way up depending on the moisture content. As it burns up at the bottom, fresh fuel tumbles down the inclined grates to replace that consumed. The purpose of the tilted bridgewall is to deflect the flame against the descending fresh fuel on the grate.

This design possesses certain advantages over spout feeding in that it provides a more uniform and much thinner fuel bed through which preheated air can be forced to speed the drying action. Also, the flames from the lower portion of the grates are probably more effective in their scrubbing and radiant action on the upper section. Ash and sand sift through the inclined grates and can also be dumped intermittently at the bottom section without interfering seriously with the fire. However, there is still a more or less dead region at the top of the grates where the fresh fuel enters, and a smoky screen forms here, as in the case of spout feeding. Furthermore, it is possible for avalanching of the fuel to occur and smother the fire in spots, expose bare grates to overheating, or to permit passage of excessive air through the bare spots.

Factors Limiting Combustion Rates

Bark and wood fuel can be burned as fast as heat can be supplied for the evaporation of moisture and distillation of the volatile matter, and combustion rates may be considered as limited by the following factors:

1. Moisture.
2. Particle size.
3. Time interval of particle suspension, in the gas stream, if feed is through the gas.
4. Sand and ash content.

As mentioned previously bark moisture is greatly affected by the method used in transporting the logs and barking them. After barking it can only be reduced by either pressing or drying or both.

Particle size is a variable that is subject to control also. It is governed by the economics involved in hogging and screening, and to some extent on the method of distributing the fuel in the furnace.

The time during which a particle is in suspension in the gas stream (if fed through the gases) can be controlled by the height of the point of introduction, the turbulence below the point of introduction, and the upward velocity of the furnace gases.

The sand and ash content can limit the combustion rate in any bark-burning method when it cannot be removed continuously. Sand and ash accumulations gradually build up resistance to underfire air flow and are thereby likely to unbalance the air distribution.

New Methods Hold Promise

Recent developments hold promise of great improvement in bark- and wood-burning methods which have remained more or less static over a number of years.

One of the methods now under study employs underfeeding in which the fresh fuel, instead of being deposited on the top of the cone, is forced up from the bottom by means of a ram. Both underfire and overfire air, under close control, are employed and relatively high combustion rates are indicated without undue carryover. Air leakage through overhead spouts is entirely eliminated with such feeding of the fuel.

Another promising method employs an overfeeding spreader which distributes the fuel uniformly over a thin fuel bed on a flat grate with the air supplied both from below and from above at high velocity by steam jets. Length of throw is governed by particle size and moisture, as is also the combustion rate. Ash and sand, if present, may be removed preferably by a continuous-discharge traveling grate, although flat, stationary or dumping grates can be used and one section at a time cleaned.

Floating Test Laboratory

Information on a floating test laboratory to study casualty conditions in turbines has just been announced by the General Electric Company with permission of the Navy Department. Set up last year aboard the *S.S. Noa* by the Navy's Bureau of Ships, the measuring instruments and correlating data make possible a check on failures in turbines under controlled abnormal conditions.

It is pointed out that each piece of steel in a turbine responds in expansion to any change in temperature of the steam to which it is exposed, and when some casualty condition alters the normal temperature gradient in the turbine, thermal expansion may upset the designed clearances. Casualty conditions may be imposed by derangement of some equipment external to the turbine, such as lost vacuum, etc.

To obtain the required data 44 thermocouples were placed at selected points in casings of the cruising turbine, the high-pressure turbine and the low-pressure turbine, and pressure-measuring devices were installed to measure very small variations in pressure.

Underground Coal Gasification Report

Pioneer accomplishments of the first government-sponsored attempt to burn unmined coal to produce gas in the United States—technically termed the underground gasification of coal in place—are described in detail in a report released on September 14 by the Bureau of Mines.

The successful gasification experiment, conducted jointly by the Bureau and the Alabama Power Company at Gorgas, Ala., between January 21 and March 12, 1947, represented an important phase of the Bureau's comprehensive research program on the carbonizing properties of coal and by-product yields and the production of synthetic liquid fuels.

The publication of the final and complete results of the 50-day experiment and the subsequent examinations of the underground workings mark the first time in the United States—and probably the world—that such detailed information has been made available. Although underground gasification of coal is new to this country, the process has been in practical use in Russia for many years and continued expansion is expected in the Soviet. However, comparatively little technical information has been published.

All of the primary and secondary objectives were achieved during the initial gasification experiment at Gorgas. Without consideration of commercial cost factors, the 50-day project determined that coal in place could be burned successfully; that the burning could be controlled; that the action of the roof appeared favorable for underground gasification because no interfering roof falls occurred; and that the quantity and heating value of the gas produced per pound of coal burned varied with the several types of blasting.

In preparing for the test, the experimental area at the Gorgas mine was isolated from adjoining coal by outcrops on three sides and an open cut on the fourth side. A U-shaped mine was developed in the coal bed, lying horizontally 30 ft under a hilltop, to form a pillar of solid coal 40 ft wide and 150 ft long inside the "U."

Five types of blasting were used to produce gas-air, oxygen-air, oxygen-air-steam, oxygen-steam and steam blasts. By regular sampling and analyses of gases given off, it was determined that the first three methods produced gases that could be used for generating power, while the oxygen-steam and steam blasts yielded gases suitable for synthesis purposes.

At the conclusion of the gas-making runs, the mine was cooled first with steam and then with water to permit examination of the underground residue and to measure the amount of coal burned. It was estimated that 236 tons of coal had been burned completely and 164 tons were coked during the combustion period.

One of the encouraging features of the entire experiment was the action of the roof during the burning process. Instead of falling as anticipated, the roof rock became plastic under the intense heat and expanded and settled down on the mine floor directly behind the reacting coal face. Tests showed that this roof action resulted in a uniform size opening for air

and gas passage along the coke-rock interface.

Of the five types of blasts, air alone was used most frequently during the experiment. For each pound of coal burned, this method produced an average of 108 cu ft of gas having a weighted average of 47 Btu per cu ft. Comparative heating values for other methods were 200 Btu per cu ft with steam runs following air blasting; 50 Btu for the air-oxygen blast; 110 Btu for the air-oxygen-steam blast; and 135 Btu for the oxygen-steam blast. These average results are considerably lower than were obtained under the most favorable conditions during the investigation.

In addition to a detailed description of the successive stages of the development of the gasification project, tests during the actual burning, and the examination of the cooled mine, the illustrated Bureau report includes an appendix describing the laboratory test of roof rock and a chronological history of the experiment from the ignition of the fire on January 21 to the end of the forced burning of coal on March 12, 1947.

Applied Mathematics Laboratories Established by Bureau of Standards

A federal center of applied mathematics, named the National Applied Mathematics Laboratories, has been established as a division of the National Bureau of Standards. Organized to conduct research and to provide service in the field of applied mathematics, the new organization is oriented around modern mathematical statistics as applied to the physical and engineering sciences and to the development and use of high-speed computing.

The new division will comprise four separate laboratories: the Institute of Numerical Analysis, located at the University of California and underwritten for the next two years by the Office of Naval Research; the Computation Laboratory, located at the Bureau and also underwritten by the Navy; the Statistical Engineering Laboratory which provides a general consulting service to both government agencies and private organizations; and the Machine Development Laboratory which is charged with the development and construction of computing machines.

Measures Adopted to Relieve New England Power Shortage

The Federal Power Commission has authorized the Connecticut Light & Power Company and The United Illuminating Company to use emergency connections to supply electric energy to assist in relieving a power shortage on the New England electric system serving Vermont, New Hampshire, Massachusetts and part of Rhode Island.

Findings of the Commission indicated that factors contributing to the emergency include a shortage of facilities for the generation and transmission of electric energy, unprecedented increase in load, unusual outages of equipment and unexpected lack of rainfall resulting in depletion of water storage.

New Books

Pressure Vessels for Industry First Edition

By Harry M. Spring, Jr.

Directed primarily to plant engineers responsible for the operation of pressure vessels, the text covers such vessels as are used for compressed-air systems, steam and hot-water services, pulp and paper mill processes, the rubber industry, textile mills, selected chemical industries and various specialized services. This is supplemented by chapters on design and stress calculations, pressure-vessel appliances, defects, repairs and the prevention of hazards. An appendix contains useful charts and conversion tables as well as a tabulation of state regulations for pressure vessels. Steam boiler rules are not included.

The author is a commissioned boiler inspector, as well as a registered professional engineer, and has maintained a practical treatment throughout the text.

There are 259 pages, $5^1/_2 \times 8$ in. with cloth binding and fully illustrated. The price is $3.50.

Fuel Savings Bulletin

Answering hundreds of practical questions on fuel saving practices and fuel conservation measures, the Bureau of Mines has combined in a single publication all of the material used successfully in the wartime National Fuel Efficiency Program.

Launched during the war as a part of the nation's critical resources conservation campaign, this program enlisted the aid of more than 20,000 volunteer workers in industrial plants, office buildings, apartment houses, schools, churches, hospitals and theaters throughout the country to save fuel. The most effective material distributed during the two-year campaign proved to be an extensive series of question-and-answer "quiz" sheets covering nearly every phase of fuel saving. All of these "quiz" sheets are included in the present Bureau publication, issued as Bulletin 466 and for sale through the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., for 50 cents.

Compressed Air Handbook First Edition

Compiled by Compressed Air and Gas Institute

This handbook is published to meet widespread demands for a reference text on applications, installation, operation and maintenance of compressing equipment and air-powered tools of all types. In addition to making available a mass of new and original data not heretofore published in a single volume, it contains, in revised and improved form, all of the standard reference material formerly pub-

lished as "Trade Standards." Included are definitions, test standards and numerous basic tables and formulae having reference to compressed air. In other words, the object was to provide a comprehensive volume of reference data which would meet technical and engineering needs and, at the same time, serve the layman and student with information on the wide versatility, flexibility and utility of modern compressed air power.

The text represents the collective knowledge, experience and thought of the nineteen member companies of the Compressed Air and Gas Institute, and was compiled over a two-year period as a joint activity of the Institute's educational committees.

There are 400 pages, 6 × 9 in., 247 illustrations, and the binding is a stiff-backed simulated-leather cover. The price is $3 in the United States and $3.50 elsewhere.

Air Conditioning and Elements of Refrigeration

By Samuel P. Brown

The objective of this book is to provide a complete, practical working handbook, as well as textbook, for study or use in design, installation or operation of heating, ventilating and air conditioning of buildings. The author is Staff Engineer of the consulting engineering firm of Coverdale and Colpitts, New York, and formerly Chief Instructor, Vocational Division, Delehanty Institute.

The phases of basic science are explained at considerable length whenever necessary as a preliminary to understanding some phase of air conditioning. Included are physical properties of air and other gases, as well as the thermodynamic properties of steam. Thus the book is suitable for vocational students, persons engaged in this field as well as technical students who may wish to review or enlarge their knowledge of air conditioning and refrigeration.

The test contains illustrative practical problems as well as typical manufacturers' rating data. Included in the appendix are steam tables, tables on properties of various refrigerants and coefficients of transmission of various types of wall construction.

The book contains 644 pages, 6 × 9 in. and is priced at $6.00.

Increased Gross, Decreased Net

Despite an increase of more than ten per cent in the total of gross operating revenues for July 1947 over that for July 1946, the combined net income of the larger privately owned electric utilities in the United States was down 5.6 per cent. These figures are contained in a report of the Federal Power Commission which shows a total gross income of $294,282,000 for July 1947 and $266,866,000 for July 1946, with the net incomes $42,083,000 and $44,570,000, respectively. Increase in operating expenses and taxes, amounting to 14.1 per cent, accounted for this situation.

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